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DEMERSAL ELASMOBRANCHS OF THE SEA OF MARMARA: UPDATED INVENTORY, TAXONOMIC ISSUES, AND ENVIRONMENTAL IMPLICATIONS

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ABSTRACT

A total of 16 elasmobranch species (nine shark and seven batoid species) were sampled in the Sea of Marmara (SoM) between 2014 and 2024 for this study. During the same period, an additional nine species (six shark and three batoid species) were recorded from the same area by other researchers. Over the past 100 years, 32 species of demersal elasmobranchs (16 shark and 16 batoid species) have been reported from the SoM, but applying "evidence-based confirmed or unconfirmed presence" criteria reduces the current number to 25 (15 shark species, 10 batoid species). Principal Component Analysis indicates that adaptability to shallower waters is now critical to the spatial distribution of demersal elasmobranchs in the SoM. This shift clearly shows how dramatically the environmental degradation, marine pollution, and deoxygenation have reduced the region's elasmobranch fauna primarily to demersal species over the last 40 years, underscoring the potentially devastating impact of such degradation on biodiversity.

Key words: Elasmobranchii, survival, conservation, inventory, Sea of Marmara,Turkey

ELASMOBRANCHI DEMERSALI DEL MARE DI MARMARA: INVENTARIO AGGIORNATO, QUESTIONI TASSONOMICHE E IMPLICAZIONI AMBIENTALI

SINTESI

Per questo studio, tra il 2014 e il 2024 sono state campionate nel Mar di Marmara (SoM) un totale di 16 specie di elasmobranchi (nove specie di squali e sette specie di batoidi). Nello stesso periodo, altri ricercatori hanno registrato altre nove specie (sei specie di squali e tre specie di batoidi) nella stessa area. Negli ultimi 100 anni, nel SoM sono state segnalate 32 specie di elasmobranchi demersali (16 specie di squali e 16 specie di batoidi), ma applicando i criteri di "presenza confermata o non confermata basata su prove" il numero attuale si riduce a 25 (15 specie di squali e 10 specie di batoidi). L'analisi delle componenti principali indica che l'adattabilità alle acque meno profonde è ora fondamentale per la distribuzione spaziale degli elasmobranchi demersali nel Mar di Marmara. Questo cambiamento mostra chiaramente come il degrado ambientale, l'inquinamento marino e la deossigenazione abbiano ridotto drasticamente la fauna di elasmobranchi della regione, principalmente alle specie demersali, negli ultimi 40 anni, sottolineando l'impatto potenzialmente devastante di tale degrado sulla biodiversità.

Parole chiave: Elasmobranchii, sopravvivenza, conservazione, inventario, Mar di Marmara, Turchia

INTRODUCTION

Fauna inventories provide the most direct means of assessing the components of animal diversity in a specific biome or locality at a given time (Silveira *et al.,* 2010). From this perspective, the elasmobranch species inventory of the Sea of Marmara (SoM) has been updated many times in studies by various researchers over the past 100 years. These studies either (1) include elasmobranchs as part of the region's general ichthyofauna (Ninni, 1923; Deveciyan, 1926; Rhasis Erazi, 1942; Kocataş *et al.,* 1993; Eryılmaz & Meriç, 2005; Torcu Koç *et al*., 2012; Daban *et al*., 2021; Bilecenoğlu, 2024), or (2) focus specifically on the elasmobranch fauna of the SoM (Kabasakal, 2016, 2022; Artüz & Fricke, 2024; Karadurmuş & Sarı, 2024; Kabasakal & Karakulak, 2024). In one of the earliest general ichthyological studies listing sharks and batoids, Ninni (1923) reported 21 elasmobranch species among the 162 fish species landed at Istanbul Wholesale Fish Market. In another pioneering study, Deveciyan (1926) provided detailed information on 16 species of sharks and batoids landed at the same market. However, neither author specified the exact locations in the SoM where these elasmobranchs were captured. Although the most recent surveys report 35 (Bilecenoğlu, 2024) and 38 (Artüz & Fricke, 2024) elasmobranch species in the ichthyofauna of the SoM, the number of species with confirmed current presence in the region decreases to 25 (Kabasakal & Karakulak, 2024) when evidence-based confirmation criteria are applied (Kovačić *et al.,* 2020).

Based on commercial landings data, several researchers have pointed to a dramatic reduction (of up to 98%) in demersal elasmobranch species in the SoM over the past three decades (Demirel *et al*., 2020; Gül & Demirel, 2021). It has recently been suggested that this decline is primarily due to overfishing and deteriorating environmental conditions, particularly the deoxygenation of bottom waters (Kabasakal, 2025). According to Silveira *et al*. (2010), fauna inventories are essential for assessing projects with myriad environmental impacts, many of which may be significant and irreversible. Therefore, creating an accurate 'snapshot' of the specific locality to be impacted is a task of utmost importance and responsibility. Given that proper species identification is the foundational step in effective fisheries management (Stauffer Jr. & Kocovsky, 2007), updating the inventory of demersal elasmobranchs in the environmentally degraded and deoxygenated SoM is a critical initiative that extends far beyond mere taxonomic curiosity. The present article provides an updated and confirmed list of demersal elasmobranch species in the SoM, based on the latest environmental monitoring and stock assessment surveys. In addition, it discusses key environmental threats to the future survival of these species in the SoM, as well as factors contributing to taxonomic inconsistencies.

MATERIAL AND METHODS

An overview of the SoM

A significant environmental issue currently threatening marine ecosystems is the emergence and expansion of 'dead zones' – hypoxic or anoxic marine areas caused by human activity (Diaz, 2016). The SoM is experiencing severe hypoxia in its deep waters, with conditions in some areas progressing towards anoxia (Mantıkçı *et al*., 2022; Salihoğlu *et al*., 2022). Hypoxia in seawater is defined as a decrease in dissolved oxygen (DO) concentration to below 2 mg/L (or 80 µM; Diaz & Rosenberg, 2008; Vaquer-Sunyer & Duarte, 2008). The SoM, designated as geographical subarea (GSA) 28 by the General Fisheries Commission for the Mediterranean (GFCM, 2018), is one of the most damaged marine ecosystems in the Mediterranean Basin (Saygu *et al*., 2023).

It is a relatively small marine basin with a surface area of 11,500 km² and a maximum depth of 1,390 m, connected to the Mediterranean and Black Seas through narrow straits (Beşiktepe *et al*., 1994; Fig. 1). Its hydrographic characteristics are largely shaped by water exchange through these straits. A distinctive feature of this system is the persistent oxygen deficiency in the deeper sub-halocline layers (Ünlüata & Özsoy, 1988; Beşiktepe *et al*., 1994).

Acting as a receiving and settling basin for organic matter transported from the Black Sea via the Bosphorus Strait (Ünlüata & Özsoy, 1988; Yılmaz *et al*., 1990), the SoM has experienced substantial ecological degradation over the past four decades due to increasing anthropogenic pressures. As a result of eutrophication, DO concentrations – particularly in bathyal waters – have fallen below the hypoxia threshold (Yılmaz *et al*., 1990; Mantıkçı *et al*., 2022). In the eastern and northeastern parts of the SoM, where deoxygenation is most severe, hypoxic conditions now extend onto the continental shelf (ÇŞİDB, TUBİTAK-MAM, 2021, p. 27; Kabasakal, 2025).

Bottom trawl surveys

The bottom trawl surveys conducted throughout the SoM (Fig. 1) between 2014 and 2024 were mainly carried out as part of two projects: (1) the Stock Assessment of Demersal Fish Species in the Eastern Marmara Sea (Project No. 51922), and (2) the Marine Monitoring (DEN-İZ) project of the Ministry of Environment, Urbanisation and Climate Change.

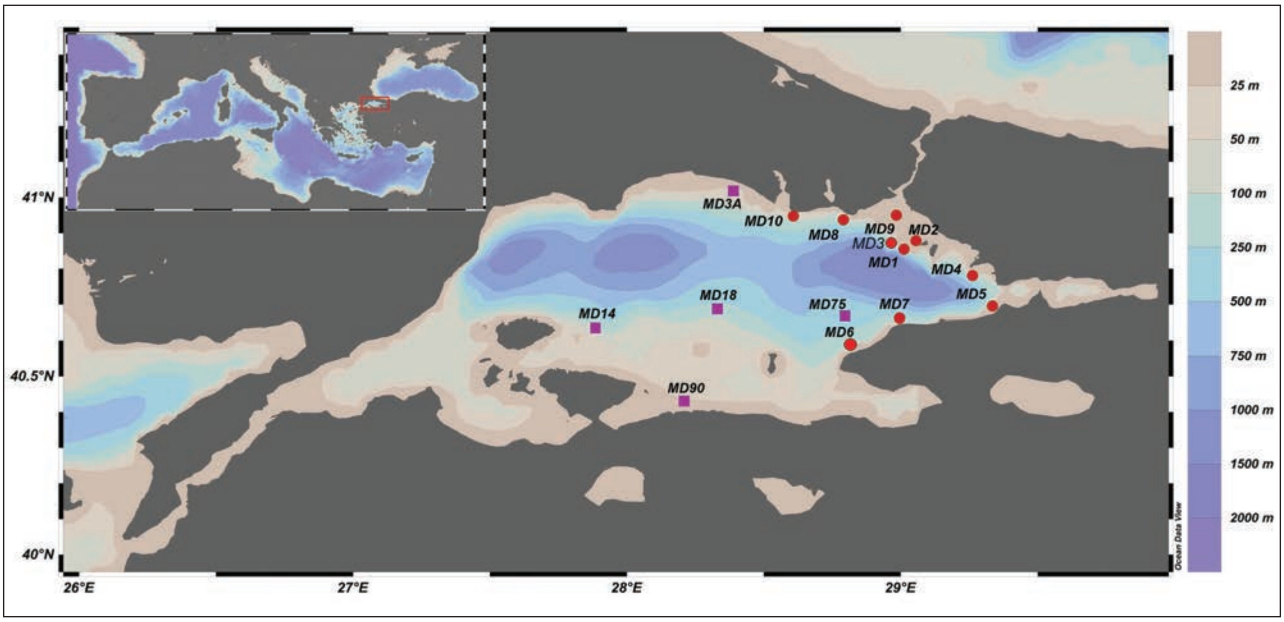

Fig. 1: Map of the study area showing sampling stations. Solid red circles denote the fixed stations of Project 51922, and solid purple squares indicate the fixed stations of DEN-İZ project.
Sl. 1: Zemljevid obravnavanega območja raziskave, ki prikazuje vzorčevalne postaje. Rdeči krogi označujejo fiksne postaje projekta 51922, vijolični kvadratki pa fiksne postaje projekta DEN-IZ.

Sampling was performed on board *R/V Yunus-S*, a 510 hp stern trawler operated by the Istanbul University's Faculty of Aquatic Sciences. A bottom trawl with a cod-end mesh size of 14 mm (approximately 22 mm mesh opening) was used for the hauls following the MEDITS protocol (Anonymous, 2017). Haul duration was set at 30 min for depths under 200 m and 60 min for depths over 200 m, with a standard towing speed of 3 knots (Anonymous, 2017). Oceanographic parameters (salinity, S; temperature, T; and dissolved oxygen, DO) were recorded using a SeaBird CTD probe. The start and end coordinates of each trawl haul, along with the corresponding seafloor depths, were determined using the vessel's onboard GPS and echo sounder.

Handling of specimens and species identification

To reduce at-vessel mortality and increase post-release survival of captured sharks and rays, we followed best-practice procedures proposed by Saygu and Deval (2014) and Ellis *et al*. (2016a). An on-board survival tank was improvised using a large container with a continuous supply of fresh seawater via a hose. Large specimens were handled according to the FAO and ACCOBAMS (2018) guides. All individuals were counted, weighed, and measured as soon as possible. With the exception of a few voucher samples, the remaining elasmobranch catch was gently released. Voucher samples are preserved at the laboratory of the Department of Fisheries Technologies and Management, Faculty of Aquatic Sciences, Istanbul University. For very large specimens (e.g., *Hexanchus griseus* or *Echinorhinus brucus*), photographs were taken and are kept in the authors' personal archives. Species identification is based on Serena (2005), Ebert and Stehmann (2013), Last *et al*. (2016), Ebert *et al*. (2021), and Barone *et al*. (2022). Scientific names follow WoRMS Editorial Board (2025).

The current status of elasmobranch species not sampled in the present survey, but known to occur in the SoM from previous studies (Ninni, 1923; Rhasis Erazi, 1942; Geldiay, 1969; Anonymous, 1974; JICA, 1993; Benli *et al*., 1993; Meriç, 1995; Uysal *et al*., 1996; Zengin *et al*., 2004; Yaka & Yüce, 2006; Torcu Koç *et al*., 2012; Yıldız *et al*., 2016; Bilecenoğlu, 2019; Kabasakal *et al*., 2023a, 2024a,b; Karadurmuş & Sarı; 2024), was assessed using evidence-based criteria for confirmed and unconfirmed presence (Kovačić *et al*., 2020). Detailed descriptions of these criteria are provided by Kovačić *et al*. (2020).

Dispersal/settlement success of demersal elasmobranch species

Principal Component Analysis (PCA) was used to examine the effect of life history characteristics and bathymetric distribution on the past and present abundance of demersal elasmobranch species in

Tab. 1: Species-specific life history traits used in the PCA of demersal elasmobranch species of the SoM. TL – total length; L_mM, L_mF length at 50% sexual maturity (males, females); GL – generation length. Continues in the next section.

Tab. 1: Vrstno specifične značilnosti življenjskega cikla, uporabljene pri PCA pridnenih vrst rib v Marmarskem morju. TL – skupna dolžina; L_mM, L_mF – dolžina pri doseženi 50% spolni zrelosti (samci, samice); GL – dolžina generacije. Nadaljevanje v naslednjem razdelku.

Species	FAO code	TL (cm)	L_mM (cm)	L_mF (cm)	GL (years)
Hexanchus griseus (Bonnaterre, 1788)	SBL	600	400	330	53
Galeus melastomus Rafinesque, 1810	SHO	90	42	45	5.7
Scyliorhinus canicula (Linnaeus, 1758)	SYC	80	56	60	?
Scyliorhinus stellaris (Linnaeus, 1758)	SYT	162	77	79	20
Mustelus asterias Cloquet, 1819	SDS	140	85	96	13
Mustelus mustelus (Linnaeus, 1758)	SMD	175	112	124	17.8
Mustelus punctulatus Risso, 1827	MPT	190	88.5	100	17.8
Galeorhinus galeus (Linnaeus, 1758)	GAG	195	170	185	30
Dalatias licha (Bonnaterre, 1788)	SCK	182	100	120	28.7
Oxynotus centrina (Linnaeus, 1758)	OXY	150	60	66	20
Centrophorus uyato (Rafinesque, 1810)	CPU	128	91	89	20
Squalus acanthias Linnaeus, 1758	DGS	195	64	93	8
Squalus blainville (Risso, 1827)	QUB	92	56	60	19.5
Echinorhinus brucus (Bonnaterre, 1788)	SHB	394	190	230	30
Squatina oculata Cuvier, 1829	SUT	160	82	100	12
Squatina squatina (Linnaeus, 1758)	AGN	244	132	169	11
Tetronarce nobiliana (Bonaparte, 1835)	TTO	180	?	?	?
Torpedo marmorata Risso, 1810	TTR	100	44	49	16
Torpedo torpedo (Linnaeus, 1758)	TTV	60	?	?	12.5
Dipturus batis (Linnaeus, 1758)	RJB	285	197.5	185.5	20
Dipturus oxyrinchus (Linnaeus, 1758)	RJO	150	103.5	91	10
Leucoraja naevus (Müller & Henle, 1841)	RJN	81	56.16	54.96	8
Raja asterias Delaroche, 1809	JRS	75	56	52	4.36
Raja clavata Linnaeus, 1758	RJC	105	85	75	11.5
Raja miraletus Linnaeus, 1758	JAI	63	41.8	34.3	7.2
Raja montagui Fowler, 1910	RJM	102	60.7	53.74	7
Raja radula Delaroche, 1809	JAR	70	46	40	9
Dasyatis pastinaca (Linnaeus, 1758)	JDP	69.5	32	38	7.5
Dasyatis tortonesei Capapé, 1975	JDO	80	38	47	?
Gymnura altavela (Linnaeus, 1758)	RGL	400	105	102	7
Aetomylaeus bovinus (Geoffroy St. Hilaire, 1817)	MPO	222	90	90	15
Myliobatis aquila (Linnaeus, 1758)	MYL	183	40	60	11

Tab. 1 (Continued): MRD – maximum recorded depth range; CDR – common depth range; TRL – trophic level. Continues in the next section.
Tab. 1 (nadaljevanje): MRD – največji zabeleženi razpon globin; CDR – običajni razpon globin; TRL – trofična raven. Nadaljevanje v naslednjem razdelku.

Species	MDR (m)			MDR (m)	CDR (m)			CDR (m)	TRL
	200–500	501–1000	>1000		0–100	101–200	>200		
H. griseus	0	0	1	2500	0	0	1	200–1100	4.48
G. melastomus	0	0	1	2000	0	0	1	200–500	4.2
S. canicula	0	1	0	800	1	1	1	0–450	3.8
S. stellaris	1	0	0	380	1	0	0	20–63	4
M. asterias	1	0	0	200	1	1	0	0–200	3.6
M. mustelus	0	1	0	800	1	0	0	5–50	4.3
M. punctulatus	1	0	0	200	1	1	0	0–200	3.8
G. galeus	0	1	0	800	1	1	1	0–800	4.3
D. licha	0	0	1	1800	0	0	1	1800	4.2
O. centrina	0	1	1	805	1	1	1	35–805	3.1
C. uyato	0	0	1	1400	0	1	1	115–745	4.5
S. acanthias	0	0	1	1978	1	1	1	0–600	4.4
S. blainville	0	0	1	1500	1	1	1	15–1500	4
E. brucus	0	0	1	1214	1	1	1	10–1214	4.4
S. oculata	1	0	0	500	1	0	0	50–100	4
S. squatina	1	0	0	150	1	1	0	1–150	4.1
T. nobiliana	0	1	0	800	1	1	0	10–150	4.5
T. marmorata	1	0	0	370	1	1	0	2–370	4.5
T. torpedo	1	0	0	400	1	0	0	2–70	4.5
D. batis	0	1	0	1000	1	1	1	30–600	4.1
D. oxyrinchus	0	1	1	1461	0	0	1	200	3.5
L. naevus	0	1	0	900	1	1	0	20–250	3.6
R. asterias	0	1	0	700	1	0	0	20–50	3.5
R. clavata	0	1	1	1020	1	0	0	10–60	4.2
R. miraletus	1	0	0	462	1	1	0	50–150	3.8
R. montagui	1	1	0	530	1	1	0	20–120	4
R. radula	1	0	0	300	1	1	1	0–300	3.7
D. pastinaca	1	0	0	200	1	0	0	20–35	4.1
D. tortonesei	1	0	0	200	0	1	0	100–200	4
G. altavela	1	0	0	100	1	0	0	5–100	4.5
A. bovinus	1	0	0	150	1	1	0	10–150	3.8
M. aquila	1	0	0	300	1	1	0	1–300	3.6

Tab. 1 (Continued): DFRSoM – Date of first record in the Sea of Marmara; DLRSoM – Date of last record in the Sea of Marmara; SLF – continental shelf; SUS – shelf–upper slope; DWT – deep bathyal water. Data on L_mM, L_mF, GL, and TRL were obtained from the literature cited in the reference column.

Tab. 1 (nadaljevanje): DFRSoM – Datum prvega zapisa v Marmarskem morju; DLRSoM – Datum zadnjega zapisa v Marmarskem morju; SLF – kontinentalni prag; SUS – kontinentalni prag–zgornje pobočje; DWT – globoki batial. Podatki o L_mM, L_mF, GL in TRL so bili pridobljeni iz literature, navedene v referencah.

Species	Before 1990	DFR SoM	DLR SoM	After 2000	SLF	SUS	DWT	Reference
H. griseus	1	1923	2022	1	0	1	1	Finucci *et al.* (2020)
G. melastomus	0	1993	2017	1	0	1	1	Abella *et al.* (2016)
S. canicula	1	1923	2024	1	1	1	0	Serena *et al.* (2015)
S. stellaris	1	1923	2023	1	1	0	0	Ellis *et al.* (2016b)
M. asterias	1	1969	2024	1	1	0	0	Farrell *et al.* (2016a)
M. mustelus	1	1923	2024	1	1	0	0	Farrell *et al.* (2016b)
M. punctulatus	0	2023	2023	1	1	0	0	Ebert *et al.* (2021)
G. galeus	1	1923	2021	1	1	0	0	McCully *et al.* (2016)
D. licha	0	1991	1991	0	0	1	0	Walls & Guallart (2016)
O. centrina	1	1942	2024	1	0	1	0	Soldo & Guallart (2016)
C. uyato	0	1992	2019	1	0	1	1	Guallart & Walls (2015)
S. acanthias	1	1923	2023	1	1	1	0	Ellis *et al.* (2016c)
S. blainville	1	1923	2024	1	1	1	0	Soldo *et al.* (2016)
E. brucus	1	1923	2023	1	1	1	1	Ferretti & Buscher (2016)
S. oculata	0	1995	2018	1	1	1	0	Ferretti *et al.* (2016a)
S. squatina	1	1923	2023	1	1	0	0	Ferretti *et al.* (2016b)
T. nobiliana	?	?	?	?	1	1	0	Finucci *et al.* (2021)
T. marmorata	1	1923	2023	1	1	1	0	Notarbartolo di Sciara *et al.* (2016)
T. torpedo	1	1923	2023	1	1	1	0	Serena *et al.* (2016a)
D. batis	1	1923	2023	1	1	1	0	Ellis *et al.* (2021)
D. oxyrinchus	1	1923	2024	1	0	1	1	Ellis *et al.* (2016d)
L. naevus	1	1996	1996	0	1	1	0	Ellis & Dulvy (2016)
R. asterias	0	1996	2009	1	1	0	0	Serena *et al.* (2016b)
R. clavata	1	1923	2023	1	1	0	0	Ellis *et al.* (2016e)
R. miraletus	1	1923	2014	1	1	0	0	Dulvy *et al.* (2020)
R. montagui	1	1996	1996	0	1	0	0	Ellis *et al.* (2016f)
R. radula	0	2006	2023	1	1	1	0	Mancusi *et al.* (2016)
D. pastinaca	1	1942	2023	1	1	0	0	Serena *et al.* (2016c)
D. tortonesei	0	2016	2016	1	1	0	0	Jabado & Derrick (2021)
G. altavela	0	1984	?	0	1	0	0	Walls *et al.* (2016)
A. bovinus	0	?	2019	1	1	0	0	Walls & Buscher (2016)
M. aquila	1	1923	2024	1	1	1	0	Serena *et al.* (2016d)

the SoM (Villagra *et al*., 2022). This analysis tested the hypothesis that "demersal elasmobranch species with a wider bathymetric distribution range are more likely to have adapted to, and persisted in, the SoM". The most recent species lists (Artüz & Fricke, 2024; Kabasakal & Karakulak, 2024; Karadurmuş & Sarı, 2024) were consulted to compile the life history parameters of the 32 demersal elasmobranch species reported from the SoM over the past century and currently categorised as 'present', 'absent' or 'doubtful' in this region. Information on the species' first and last recorded occurrences (date of first record in the Sea of Marmara (DFRSoM) and date of last record in the Sea of Marmara (DLRSoM) in Table 1), as well as depth distribution in the SoM (continental shelf occurrence (SLF), shelf-upper slope occurrence (SUS) and deep bathyal water occurrence (DWT) in Table 1) were retrieved from the literature (Tab. 1), specifically from Ninni (1923), Rhasis Erazi (1942), Geldiay (1969), Anonymous (1974), JICA (1993), Benli *et al*. (1993), Meriç (1995), Uysal *et al*. (1996), Zengin *et al*. (2004), Yaka and Yüce (2006), Torcu Koç *et al*. (2012), Yıldız *et al*. (2016), Bilecenoglu (2019), Kabasakal *et al*. (2023a, 2024a, b), and Karadurmus and Sarı (2024). The sources for data on total length (TL), male and female sexual maturation lengths (L_mM and L_mF, respectively), generation length (GL), depth distribution, and habitat are provided in Table 1. These life history parameters, compiled from the literature, were first organised in a raw data table. A matrix was then formulated where these data were expressed as numerical values (maximum TL and sexual maturation length in cm; GL in years; trophic level) and binary values (0 for absent and 1 for present). The PCA analysis was based on this final data matrix (Villagra *et al*., 2022), using PAST - Paleontological Statistics ver. 4.03 (Hammer *et al*., 2001; Rincón-Díaz *et al*., 2018).

RESULTS AND DISCUSSION

Updated species inventory and taxonomic issues

Sixteen elasmobranch species (nine sharks and seven batoids; Tab. 2) were sampled between 2014 and 2024 in the present study (Fig. 2). During the same period, an additional nine species (six sharks and three batoids; Table 2) were recorded in same area by Bilecenoğlu (2019), Daban *et al*. (2021), Kabasakal and Türetken (2021), Karadurmuş and Sarı (2024), and Kabasakal *et al*. (2024a, b). As evidenced by the ichthyological inventories presented in Table 2, a total of 32 species of demersal elasmobranchs (16 sharks and 16 batoids) have been reported from the SoM over the past 100 years. However, using the criterion proposed by Bilecenoğlu (2024) – including only species whose presence has been confirmed within the past 10 years – sets the current count at 25 (15 sharks and 10 batoids; Table 2). This figure is remarkably lower than the totals reported by Bilecenoğlu (2024; n = 34) and Artüz and Fricke (2024; n = 38), as these authors included in their checklists all shark and batoid species recorded in the SoM since 1923, regardless of whether any had been observed in the region within the past decade or not. Furthermore, the presence of the 25 species was assessed applying the criteria for "evidence-based confirmed or unconfirmed presence" proposed by Kovačić *et al*. (2020). Only 16 species have a verified presence under Criterion 1, which requires that at least one specimen from the SoM is stored in a scientific collection with a published reference. Six species were confirmed under Criterion 2, which applies where there are no stored specimens, but the species can be positively identified from a photo of the SoM locality provided in a published record. Three species were confirmed under Criterion 5; this is used when there are no stored specimens or published morphological/genetic evidence, but species citations can be traced back to an author – with expert knowledge of the taxon or fish guild of a particular habitat – who reported numerous findings (or, in a study on ecology or species biology, numerous specimens), making correct identification highly probable.

Although *Dalatias licha*, *Torpedo torpedo*, and *Leucoraja naevus* each have at least one positive historical record from the SoM and meet the criteria for verified presence (1, 5, and 2, respectively), they were not included in the updated inventory because none has been recorded in the region during the past decade. According to Bilecenoğlu (2024), *Tetronarce nobiliana* and *Gymnura altavela* are also present in the SoM; however, their listing among elasmobranch fauna of the SoM is based on a historical ichthyological inventory (Bilecenoğlu *et al*., 2014). A critical retrospective review of ichthyological checklists for the seas of Turkey, published at roughly ten-year intervals (Bilecenoğlu *et al*., 2002, 2014; Bilecenoğlu, 2024), reveals that all three studies cite the occurrence of *T. nobiliana* and *G. altavela* in the SoM based solely on Mater and Meriç (1996) – the first inventory of Turkish marine fishes. This original source, however, provides no information where the examined specimens were captured or deposited in a scientific collection for verification. Since the evidence was insufficient to confirm the contemporary occurrences of *T. nobiliana* and *G. altavela* in the SoM, the only applicable classification was exclusion Criterion 13 (Kovačić *et al*., 2020). This applies when a species' reported presence is based on a review publication citing an original reference that in itself contains no

Tab. 2: Chronological summary of demersal elasmobranch species (n=32) recorded in the SoM by different researchers between 1923 and 2024. The numbers in the top row refer to source references that reported shark and batoid records from the SoM (indicated by +). These references are as follows: (1) Ninni (1923), (2) Anonymous (1974), (3) JICA (1993), (4) Meriç (1995), (5) Mater and Meriç (1996), (6) Uysal** et al. **(1996), (7) Kabasakal (2003), (8) Zengin** et al. **(2004), (9) Yaka and Yüce (2006), (10) Torcu Koç** et al. **(2012), (11) Yıldız** et al. **(2016), (12) Bilecenoğlu (2019), (13) Kabasakal and Türetken (2021), (14) Daban** et al. **(2021), (15) Karadurmuş and Sarı (2024), (16) Kabasakal** et al. **(2023a), (17) Kabasakal** et al. **(2024a), (18) Kabasakal** et al. **(2024b), and (19) elasmobranch species captured during the 2014–2024 sampling period of the present study. Demersal elasmobranch species recorded in the SoM in the last 10 years are marked with a check (✓) in the 2025 column; these records constitute the updated list of elasmobranch species. C denotes the applicable criterion for confirmed or unconfirmed presence (Kovačić** et al.**, 2020). Elasmobranch species not included in the updated inventory are shown in bold.

Tab. 2: Kronološki povzetek pridnenih vrst hrustančnic (n=32), ki so jih v Marmarskem morju zabeležili različni raziskovalci med letoma 1923 in 2024. Številke v zgornji vrstici se nanašajo na vire, ki so poročali o zapisih o morskih psih in skatih iz Marmarskega morja (označeno z +). Ti viri so naslednji: (1) Ninni (1923), (2) Anonymous (1974), (3) JICA (1993), (4) Meriç (1995), (5) Mater in Meriç (1996), (6) Uysal in sod. (1996), (7) Kabasakal (2003), (8) Zengin in sod. (2004), (9) Yaka in Yüce (2006), (10) Torcu Koç in sod. (2012), (11) Yıldız in sod. (2016), (12) Bilecenoğlu (2019), (13) Kabasakal in Türetken (2021), (14) Daban in sod. (2021), (15) Karadurmuş in Sarı (2024), (16) Kabasakal in sod. (2023a), (17) Kabasakal in sod. (2024a), (18) Kabasakal in sod. (2024b) in (19) vrste pridnenih hrustančnic, ujete v obdobju vzorčenja 2014–2024 v tej študiji. Pridnene vrste hrustančnic, zabeležene v Marmarskem morju v zadnjih 10 letih, so označene s kljukico (✓) v stolpcu 2025; ti zapisi predstavljajo posodobljen seznam vrst hrustančnic. C označuje veljavno merilo za potrjeno ali nepotrjeno prisotnost (Kovačić in sod., 2020). Vrste hrustančnic, ki niso vključene v posodobljeni popis, so prikazane s krepko pisavo.

Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**2025**	**C**
Hexanchus griseus	+			+			+							+					+	✓	1
Galeus melastomus			+	+		+	+												+	✓	1
Scyliorhinus canicula	+	+	+	+				+		+				+	+				+	✓	1
Scyliorhinus stellaris	+	+					+	+							+					✓	2
Mustelus asterias	+		+	+			+							+	+					✓	1
Mustelus mustelus	+	+	+	+				+						+	+				+	✓	1
Mustelus punctulatus															+					✓	5
Galeorhinus galeus	+												+							✓	2
Dalatias licha				+																	1
Oxynotus centrina		+	+				+	+						+	+				+	✓	1
Centrophorus uyato			+	+												+			+	✓	1
Squalus acanthias	+	+	+	+			+	+						+	+				+	✓	1
Squalus blainville	+		+	+			+							+					+	✓	1
Echinorhinus brucus	+															+			+	✓	2
Squatina oculata																	+			✓	2
Squatina squatina	+	+	+				+							+	+					✓	1
Tetronarce nobiliana					+																13
Torpedo marmorata	+	+	+											+	+				+	✓	1
Torpedo torpedo	+	+								+											5
Dipturus batis	+	+						+							+					✓	5
Dipturus oxyrinchus	+					+												+		✓	2

Leucoraja naevus						+															2
Raja asterias					+							+									14
Raja clavata	+	+						+		+				+	+				+	✓	1
Raja miraletus	+	+													+				+	✓	1
Raja montagui					+																14
Raja radula									+										+	✓	1
Dasyatis pastinaca		+						+						+	+				+	✓	1
Dasyatis tortonesei											+								+	✓	5
Gymnura altavela					+																13
Aetomylaeus bovinus												+								✓	2
Myliobatis aquila	+	+												+	+				+	✓	1
Number of species per reference	**17**	**13**	**10**	**9**	**4**	**3**	**8**	**8**	**1**	**3**	**1**	**2**	**1**	**12**	**14**	**2**	**1**	**1**	**16**	**25**	

supporting data. Therefore, although listed in the most recent ichthyological checklist (Bilecenoğlu, 2024), *T. nobiliana* and *G. altavela* were excluded from our updated inventory.

The occurrence of *Raja asterias* in the SoM was first reported by Mater and Meriç (1996), again without information where the examined specimen was captured and without a voucher specimen stored for further inspection. In 2009, another purported specimen of *R. asterias* was recorded in the southwestern SoM (Torcu Koç *et al.*, 2012); although detailed collection data were provided (capture depth and coordinates, substratum type etc.), photographic evidence later revealed that the specimen was a misidentified juvenile *R. clavata* (Kabasakal *et al.*, 2025a). The occurrence record for *R. montagui* is also based on Mater and Meriç (1996) and does not provide the relevant information (e.g., original source reference) for this species either. Therefore, the only applicable criterion for SoM records of both *R. asterias* and *R. montagui* is exclusion Criterion 14, which is employed when a species' reported presence cited in a review publication is traceable to an original reference that, upon inspection, proves to have been based on synonymization or misidentification. Although *R. brachyura* was included in another recent elasmobranch inventory of the SoM (Artüz & Fricke, 2024), it does not appear in our updated list – not even as a 'questionable' or 'unconfirmed' species – due to its documented absence from Turkish seas (Kabasakal, 2002; Bilecenoğlu, 2024). Its inclusion in the aforementioned checklist may stem from misidentification of the polymorphic *R. clavata* (Criterion 14, Kovačić *et al.*, 2020), as emphasised by Kabasakal *et al.* (2025a).

Karadurmuş and Sarı (2024) recently reported *Mustelus punctulatus* from the SoM for the first time. However, their record was not supported by any morphological, genetic, or photographic evidence, aside from locality data. The principal diagnostic feature used to identify *M. punctulatus* is the presence of black spots on the body (Ebert *et al.*, 2021). Although Marino *et al.* (2018) note that black spots are almost exclusively associated with *M. punctulatus*, they also emphasise that their absence is not diagnostic of *M. mustelus*. Furthermore, Ebert and Stehmann (2013) pointed out that some *M. mustelus* specimens may also exhibit dark spotting. In this taxonomically challenging situation, a second diagnostic key feature for *M. punctulatus* is the presence of fringed posterior margins on the dorsal fins (Marino *et al.*, 2018). Bello *et al.* (2014) proposed a best-practice approach for avoiding unverified or unverifiable 'first records' in ichthyology, which entails the preparation and deposition of a voucher specimen in a curated collection, accompanied by photographs, meristic and morphometric data, and, where possible, a DNA sequence (barcode). This protocol was not followed for the *M. punctulatus* record reported by Karadurmuş and Sarı (2024). The same authors also reported a new occurrence of *Dipturus batis* in the SoM, based on a single specimen captured off the northern coast (Karadurmuş & Sarı, 2024). Aside from the locality data, no supporting material (e.g., morphometric data or photographs) was provided to substantiate this important record, contrary to the verification standards proposed by Bello *et al.* (2014). Although *D. batis* appears in the recent checklists of Bilecenoğlu (2024) and Artüz and Fricke (2024), its inclusion is based on two historical references (Deveciyan, 1915; Ninni, 1923). Notably, Kabasakal *et al.* (2024b) reported

Fig. 2: Examples of sharks and batoids occurring in the SoM: (a) *Hexanchus griseus**; (b)*** *Echinorhinus brucus**;*** ***(c)*** *Oxynotus centrina**; and (d)*** *Myliobatis aquila**. All specimens were held in a survival tank until examination and subsequently released alive (photos: Hakan Kabasakal & F. Saadet Karakulak).***

Sl. 2: Primeri morskih psov in skatov, ki se pojavljajo v južnem delu Marmarskega morja: (a) *Hexanchus griseus**;*** ***(b)*** *Echinorhinus brucus**; (c)*** *Oxynotus centrina**; in (d)*** *Myliobatis aquila**. Vsi primerki so bili do pregleda shranjeni v rezervoarju za preživetje in nato živi izpuščeni na prostost (fotografije: Hakan Kabasakal in F. Saadet Karakulak).***

sympatric *D. oxyrinchus* almost at the same location where Karadurmuş and Sarı (2024) claimed *D. batis*. As *D. oxyrinchus* and *D. batis* are morphologically very similar (Ebert & Stehmann, 2013; Barone *et al*., 2022), they may be confused by researchers not specialising in elasmobranchs. Because of ambiguous evidence, the presence of *M. punctulatus* and *D. oxyrinchus* in the SoM was classified as confirmed only under the lowest applicable criterion (Criterion 5; defined above). We hope that future studies will obtain additional specimens to clarify the occurrence of these elasmobranchs in the SoM, allowing their status to be assessed against more robust criteria.

Finally, a recent study showed that either a highly differentiated variety of *S. blainville* or an undescribed species within the *S. megalops* clade may occur in the SoM (Kabasakal *et al*., 2024c). Given the uncertainties surrounding several elasmobranch species – primarily arising from potential misidentifications by non-taxonomists or researchers without specialised expertise in elasmobranchology and species-specific polymorphism – a genetically informed revision of the elasmobranch fauna of the SoM is urgently needed. To summarise this section, as of 16 June 2025, the updated inventory of demersal elasmobranchs of the SoM consists of the following species: *Hexanchus griseus*, *Galeus melastomus*, *Scyliorhinus canicula*, *S. stellaris*, *Mustelus asterias*, *M. mustelus*, *M. punctulatus*, *Galeorhinus galeus*, *Oxynotus centrina*, *Centrophorus uyato*, *Squalus acanthias*, *S. blainville*, *Echinorhinus brucus*, *Squatina oculata*, *S. squatina*, *Torpedo marmorata*, *Dipturus batis*, *D. oxyrinchus*, *Raja clavata*, *R. miraletus*, *R. radula*, *Dasyatis pastinaca*, *D. tortonesei*, *Aetomylaeus bovinus*, and *Myliobatis aquila* (Tab. 2).

Dispersal/settlement success of demersal elasmobranch species

The PCA incorporating basic life history characteristics, first and last record dates, and bathymetric distribution (depth ranges) for the 32 demersal elasmobranch species recorded in the SoM (Tab. 2) explained 47.62% of the total variance (Fig. 3). In contrast, a second PCA considering only the species' first and last record dates and their common depth ranges in the SoM, accounted for a variance of approximately 61.34% (Fig. 3). While records from the SoM preceding 1990 show that elasmobranch species were more common in the deep continental shelf (100–200 m depth) and in waters deeper than 200 m, since the 2000s, these species have mostly been recorded at depths of 0–100 m. The PCA model based solely on common depth ranges and recording dates showed a 13.72% difference in explained variance compared to the PCA including basic life history parameters – such as maximum size, size at sexual maturity, and generation length – of demersal elasmobranchs. This suggests that adaptability to shallower waters is a key factor influencing the spatial distribution of demersal elasmobranch species in the SoM.

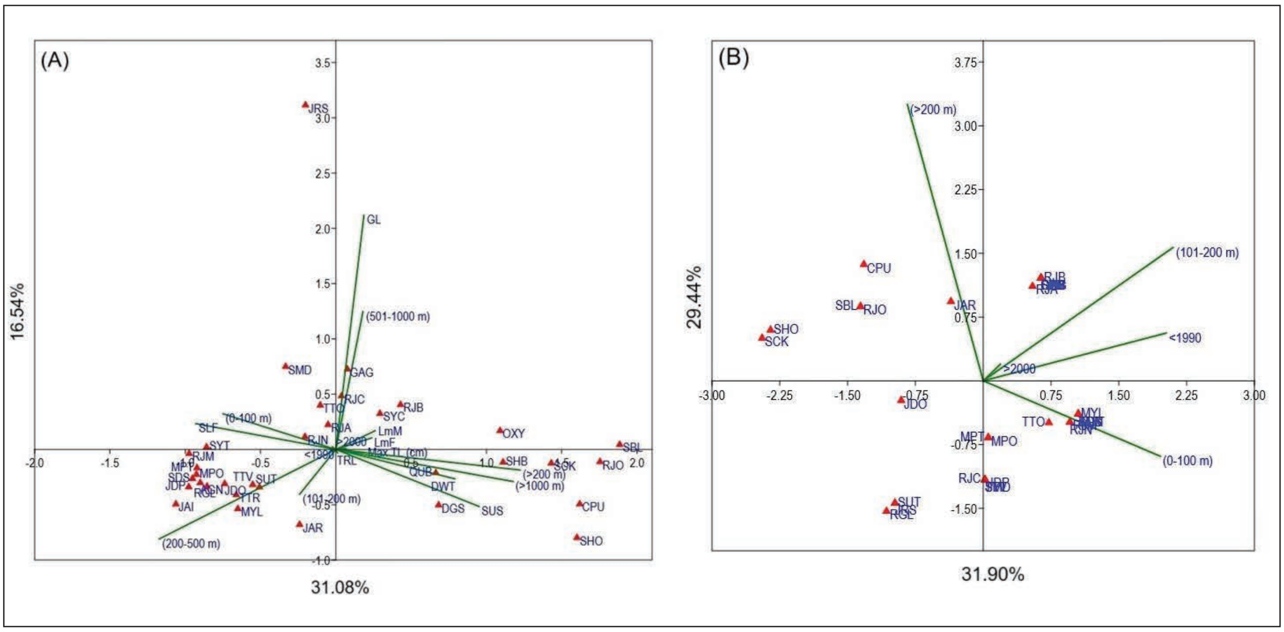

Fig. 3: Plots of Principal Component Analysis (PCA) of demersal elasmobranch species of the SoM, based on (a) all available data, and (b) only the first and last record dates and the common depths at which individuals were recorded in the SoM. The three-letter abbreviations next to the red triangles represent FAO codes for cartilaginous fishes, shown alongside their corresponding species names: Hexanchus griseus, **SBL;** Galeus melastomus, **SHO;** Scyliorhinus canicula, **SYC;** Scyliorhinus stellaris, **SYT;** Mustelus asterias, **SDS;** Mustelus mustelus, **SMD;** Mustelus punctulatus, **MPT;** Galeorhinus galeus, **GAG;** Dalatias licha, **SCK;** Oxynotus centrina, **OXY;** Centrophorus uyato, **CPU;** Squalus acanthias, **DGS;** Squalus blainville, **QUB;** Echinorhinus brucus, **SHB;** Squatina oculata, **SUT;** Squatina squatina, **AGN;** Tetronarce nobiliana, **TTO;** Torpedo marmorata, **TTR;** Torpedo torpedo, **TTV;** Dipturus batis, **RJB;** Dipturus oxyrinchus, **RJO;** Leucoraja naevus, **RJN;** Raja asterias, **JRS;** Raja clavata, **RJC;** Raja miraletus, **JAI;** Raja montagui, **RJM;** Raja radula, **JAR;** Dasyatis pastinaca, **JDP;** Dasyatis tortonesei**; JDO;** Gymnura altavela**; RGL;** Aetomylaeus bovinus, **MPO;** Myliobatis aquila, **MYL.**

Sl. 3: Diagrami analize glavnih komponent (PCA) pridnenih vrst hrustančnic v Marmarskem morju, ki temeljijo na (a) vseh razpoložljivih podatkih in (b) le na datumu prvega in zadnjega zapisa ter skupnih globinah, na katerih so bili primerki osebki zabeleženi v Marmarskem morju. Tri črkovne okrajšave poleg rdečih trikotnikov predstavljajo kode FAO za hrustančnice, prikazane poleg njihovih ustreznih imen vrst: Hexanchus griseus, **SBL;** Galeus melastomus, **SHO;** Scyliorhinus canicula, **SYC;** Scyliorhinus stellaris, **SYT;** Mustelus asterias, **SDS;** Mustelus mustelus, **SMD;** Mustelus punctulatus, **MPT;** Galeorhinus galeus, **GAG;** Dalatias licha, **SCK;** Oxynotus centrina, **OXY;** Centrophorus uyato, **CPU;** Squalus acanthias, **DGS;** Squalus blainville, **QUB;** Echinorhinus brucus, **SHB;** Squatina oculata, **SUT;** Squatina squatina, **AGN;** Tetronarce nobiliana, **TTO;** Torpedo marmorata, **TTR;** Torpedo torpedo, **TTV;** Dipturus batis, **RJB;** Dipturus oxyrinchus, **RJO;** Leucoraja naevus, **RJN;** Raja asterias, **JRS;** Raja clavata, **RJC;** Raja miraletus, **JAI;** Raja montagui, **RJM;** Raja radula, **JAR;** Dasyatis pastinaca, **JDP;** Dasyatis tortonesei**; JDO;** Gymnura altavela**; RGL;** Aetomylaeus bovinus, **MPO;** Myliobatis aquila, **MYL.**

Environmental implications

Table 3 compares the maximum recorded depths of demersal elasmobranchs in the SoM with records from other regions of the Mediterranean Basin. The table highlights notable differences in maximum recorded depths depending on the year of observation in SoM-specific studies. Specifically, in the early 1990s, elasmobranch species were recorded down to upper slope depths (≤500 m) throughout the SoM; however, since the mid-2000s, their bathymetric ranges have been restricted to shelf waters (see asterisked references in Tab. 3). The only exceptions to this narrowing of the bathymetry were observations of *E. brucus* and *G. melastomus* in the Tekirdağ Trench (northwestern SoM) at depths below 1,000 m. (Kabasakal *et al*., 2005; Oral, 2010). Several elasmobranchs (marked with an "δ") that elsewhere in the Mediterranean inhabit shelf waters as well as upper and lower slope depths (e.g., Follesa *et al*., 2019; Ruiz-García *et al*., 2023; Deval & Mutlu, 2024) have, in the SoM since the mid-2000s, had maximum recorded depths restricted to outer and even inner shelf waters (see asterisked references in Table 3). Daban *et al*. (2021) reported that the number of elasmobranch species in the SoM increases with depth, and that the highest catch per unit of effort (CPUE; kg/km^2) for *H. griseus*, *M. asterias* and *S. acanthias* was recorded at depths between 100 and 200 m. This suggests a distribution largely restricted to outer shelf waters. They also observed increased CPUE for *M. mustelus*, *S. squatina*, and several batoids at depths of 20–50 m. Karadurmuş and Sarı (2024) reported a similar shelf-restricted bathymetric distribution for elasmobranchs in the region. A recent study by Kabasakal (2025) found that the spatial distribution and abundance (number/km^2) of demersal elasmobranchs in the SoM are now restricted to the inner shelf at depths of 50–100 m. The author attributes this to vertical habitat compression, driven by deoxygenation and the emergence of dead zones in deep shelf and bathyal waters – a process particularly severe in the environmental degraded eastern SoM.

Based on correlations between captures of *H. griseus* and environmental parameters, Kabasakal *et al*. (2024d) concluded that the recent increase in bluntnose sixgill shark captures in continental shelf waters is primarily associated with an annual rise in dissolved organic compounds (NO_2+NO_3 nitrogen and PO_4 phosphorus) in bathyal waters. They also found that deteriorating environmental conditions and progressive deoxygenation in the deep waters of the SoM coincide with a reduction in the capture depth of *H. griseus* on the continental shelf. Severe hypoxia in deep continental shelf waters (>100 m) and anoxia in the slope waters of the northeastern SoM drastically constrict the bathymetric and spatial distribution of demersal elasmobranchs in the region. PCA shows that, since the 2000s, records of demersal elasmobranchs have been concentrated at depths shallower than 150 m, reflecting the ongoing mass migration of these species toward continental shelf areas. This suggests that 'adaptability to shallows on the continental shelf' is a key factor in determining the spatial distribution of these species in the SoM.

So what is the future of the demersal elasmobranchs still struggling to survive in the SoM today? According to Diaz and Rosenberg (2008), these species may recolonise their former habitats if dissolved oxygen (DO) levels and ecosystem functions improve, although they may not reach pre-hypoxia levels. Historical observations support the one-time suitability of deeper waters for demersal cartilaginous fish: *E. brucus* was recorded at 1,214 m in the Tekirdağ Trench in northwestern SoM in the early 2000s (Kabasakal *et al*., 2005), and *G. melastomus* was sampled at similar depths in the same region in 2008 (Oral, 2010). Additionally, Gallo *et al*. (2019) noted that certain elasmobranch species, such as cat sharks (e.g., *Cephalurus cephalus*), can tolerate suboxic conditions and withstand hypoxia better than previously believed. The species list presented in the 1974 Environmental Impact Assessment (EIA) report prepared by the Hydrobiology Research Institute to provide biological information prior to the construction of a sewage system discharging into the Bosphorus Strait – the gateway between the SoM and the Black Sea – offers insight into the historical species richness of elasmobranchs in the SoM (Anonymous, 1974; Fig. 4). Although the taxonomy used in the report is no longer valid, it is still possible to identify many of the listed species, especially pelagic ones, that have been absent from the region for years.

The extreme rarity of large pelagic sharks in the SoM is both remarkable and alarming. Early ichthyological inventories (Ninni, 1923; Deveciyan, 1926; Anonymous, 1974) considered the following pelagic shark species to be seasonal visitors to or residents of the region: *Alopias vulpinus*, *Cetorhinus maximus*, *Carcharodon carcharias*, *Lamna nasus*, and *Prionace glauca*. In addition, *A. superciliosus* was first recorded in the SoM in 2007 (Kabasakal & Karhan, 2008), with a second specimen captured in 2011. Since then, no *A. superciliosus* specimens have been captured or sighted. Today, all pelagic sharks except *A. vulpinus* have been extirpated from the SoM, and even incidental captures or sightings of this remaining species are becoming increasingly rare. This decline coincides with the warming of the region: over the past 20 years, the annual average sea surface temperature (SST) in the seas of Türkiye has increased by 0.4–1.4 °C due to global warming and climate change, with the SoM being the second most affected after the Black Sea (Demircan, 2022).

Tab. 3: Comparison between maximum recorded depths for demersal elasmobranchs included in the updated SoM inventory and values recorded in various studies from other regions of the Mediterranean. Notes: [§] species observed at the surface, no maximum depth record available; [μ] record based on data from a commercial fisherman, no maximum depth record available; [δ] species with bathyal distribution in Mediterranean subregions; [*] study specific to SoM.
Tab. 3: Primerjava med največjimi zabeleženimi globinami za pridnene hrustančnice, vključene v posodobljen popis vrst v Marmarskem morju, in vrednostmi, zabeleženimi v različnih študijah iz drugih regij Sredozemlja. Opombe: § - vrste, opažene na površini, ni na voljo zapisa o največji globini; μ - zapis temelji na podatkih komercialnega ribiča, ni na voljo zapisa o največji globini; δ - vrste z batialno razširjenostjo v sredozemskih podregijah; * študija, specifična za Marmarsko morje.

Species	**Present Study**	**JICA (1993)***	**Meriç (1995)***	**Kabasakal *et al.* (2005)***	**Oral (2010)***	**Torcu Koç *et al.* (2012)***	**Bilecenoğlu (2019)***	**Follesa *et al.* (2019)**	**Daban *et al.* (2021)***	**Ruiz-García *et al.* (2023)**	**Deval & Mutlu (2024)**	**Karadurmuş & Sarı (2024)***
Hexanchus griseus[δ]	188	–	350	–	–	–	–	800	200	537	–	–
Galeus melastomus[δ]	140	500	350	–	1213	–	–	800	–	685	800	–
Scyliorhinus canicula[δ]	124	500	350	–	–	60	–	800	200	649	600	146
Scyliorhinus stellaris	–	–	–	–	–	–	–	200	200	–	–	146
Mustelus asterias	–	500	350	–	–	–	–	200	200	–	–	45
Mustelus mustelus	188	100	350	–	–	–	–	200	200	–	200	85
Mustelus punctulatus	–	–	–	–	–	–	–	200	–	–	–	146
Galeorhinus galeus[§]	–	–	–	–	–	–	–	800	–	–	–	–
Oxynotus centrina[δ]	66	500	–	–	–	–	–	800	200	214	600	146
Centrophorus uyato[δ]	150	500	270	–	–	–	–	800	–	588	800	–
Squalus acanthias[δ]	140	200	350	–	–	–	–	800	200	–	–	146
Squalus blainville[δ]	140	500	350	–	–	–	–	800	200	–	600	–
Echinorhinus brucus	150	–	–	1214	–	–	–	–	–	–	–	–
Squatina oculata[μ]	–	–	–	–	–	–	–	–	–	–	–	–
Squatina squatina	–	–	–	–	–	–	–	–	50	–	–	47
Torpedo marmorata	116	200	–	–	–	45	–	200	200	257	300	85
Dipturus batis	–	–	–	–	–	–	–	–	–	–	–	68
Dipturus oxyrinchus[δ]	100	500	–	–	–	–	–	800	–	329	600	–
Raja clavata[δ]	188	500	–	–	–	45	–	800	50	329	500	146
Raja miraletus	95	–	–	–	–	–	–	200	–	–	200	85
Raja radula	25	–	–	–	–	–	–	200	–	–	–	–
Dasyatis pastinaca	84	200	–	–	–	–	–	200	50	133	200	146
Dasyatis tortonesei	67	–	–	–	–	–	–	–	–	–	–	–
Aetomylaeus bovinus	–	–	–	–	–	–	3	200	–	73	–	–
Myliobatis aquila	90	200	–	–	–	–	–	200	200	73	–	85

List of Fishes in the Project Area

A. SELACHII	I	II	III	IV	Hab.
Acanthias vulgaris (Riss.)	+++	+	–	++	D
Centrina vulpicula (Bell.)	+	–	–	+	D
Cetorhinus maximus (L.)	–	–	–	+	P
Chacharias glauca (Gm.)	–	–	–	+	P
Charcharodon charcharias (L.)	–	–	–	+	P
Charcharodon lamia (Rond.)	–	–	–	+	P
Dasyatis pastinaca (L.)	+	–	–	+	D
Mustelus mustelus (L.)	+++	+	–	+++	D
Mustelus vulgaris (Mull-Hen)	+++	+	–	+++	D
Myliobatis aquila (L.)	++	+	–	++	D
Raja batis (L.)	+	+	–	+	D
Raja clavata (L.)	+++	+++	–	+++	D
Raja mirelatus (L.)	+	+	–	+	D
Raja oculata (Risso.)	+	+	–	+	D
Raja punctata (Risso.)	+	+	–	+	D
Scyllium canicula (L.)	+	+	–	+	D
Scyllium stellare (L.)	+	+	–	+	D
Squatina squatina (L.)	+	+	–	++	D
Torpedo marmorata (Risso.)	+	+	–	+	D
Torpedo narke (Risso.)	+	+	–	++	D
Trygon pastinaca (Cuv.)	+	–	–	–	D

– not present
\+ present but rare
++ found frequently
+++ abundant

Fig 4: Pelagic and demersal elasmobranch species reported from the southern entrance of the Bosphorus Strait (northeastern SoM) in the Environmental Impact Assessment (EIA) report compiled by the Hydrobiology Research Institute (adapted from Anonymous, 1974).

Sl. 4: Pelaške in pridnene vrste hrustančnic, o katerih so poročali pri južnem vhodu v Bosporsko ožino (severovzhodni del Marmarskega morja) v poročilu o presoji vplivov na okolje (EIA), ki ga je sestavil Raziskovalni inštitut za hidrobiologijo (prirejeno po Anonymous, 1974).

This rise in seawater temperatures has reduced the solubility of DO, causing elasmobranch species to become less tolerant of hypoxia, as their metabolic rates increase in parallel with warming (Breitburg *et al.*, 2018; Waller *et al.*, 2024). Vedor *et al.* (2021) suggested that the expanding oxygen minimum zones (OMZs) driven by climate change – (through shoaling of low-DO waters and rising SST) – will compress the habitat of pelagic sharks, such as the blue shark, *P. glauca*, forcing them into surface waters above the OMZs and thereby reducing their overall available habitat volume. Such dynamic is indeed described by the OMZ 'habitat trap' hypothesis. According to Sims (2019), the high oxygen demands of pelagic sharks compel them to retreat to normoxic zones when encountering oxygen-depleted waters of the open ocean (like those in the SoM). Consequently, the apparent absence of most pelagic shark species (except *A. vulpinus*) from the SoM today is likely due to regional deoxygenation and an increased rate of their incidental capture in the resulting OMZ habitat trap. It seems that decades of environmental degradation, marine pollution, and deoxygenation in the SoM have reduced the region's elasmobranch fauna largely to demersal species. This highlights the potentially devastating impact of environmental degradation on marine fauna and biodiversity. A comparable depletion of large mesopredators such as *G. galeus* and *Carcharhinus plumbeus*, and top predators such as *A. vulpinus*, *L. nasus*, and *P. glauca*, has been recorded in the Adriatic Sea, where environmental variability, in addition to fisheries, has been suggested to impact elasmobranch abundance (Barausse *et al.*, 2014).

In conclusion, while overfishing was once considered the primary threat to chondrichthyans (sharks, rays, and chimaeras) (Stevens *et al.*, 2000), habitat degradation, pollution, and climate change are now recognised as additional major drivers of species loss in this group (Dulvy *et al.*, 2021). Based on the assessment of fish communities across several aquatic ecosystems worldwide, Moyle and Leidy (1992) concluded that most faunas are in serious decline, primarily due to commercial exploitation, habitat alteration, and pollution, and therefore require immediate protection. Pollom *et al.* (2024) reported of two South African cat shark species (*Haploblepharus fuscus* and *H. kistnasamyi*) threatened not only by overfishing but also by coastal urbanisation, industrialisation, and increasing marine pollution. The combined pressures have led to both species being categorised as 'Vulnerable' on the Red List. The findings of Pollom *et al.* (2024) align with numerous other studies demonstrating the drastic effects of human activities on regional fish faunas, as also documented by Bin Aziz *et al.* (2021) and Yang *et al.* (2024). The assumption that shallow continental shelf areas may become a habitat trap for demersal elasmobranchs – forcing these out of deep waters and exposing them to higher fishing pressure – has now materialised in the SoM, as pointed out by Kabasakal *et al.* (2023b) and Waller *et al.* (2024). According to Akoğlu *et al.* (2024), the pattern traditionally observed in demersal fishery – years of overfishing followed by stock collapse and gradual recovery over decades – no longer holds true for demersal elasmobranchs in the SoM. Although Important Shark and Ray Areas (ISRAs) have recently been designated in the SoM (Jabado *et al.*, 2023) – that confirm the presence of 25 demersal elasmobranch species and encompass potential breeding grounds for various taxa (e.g., *S. canicula*, *O. centrina*, *S. blainvillei* and *M. aquila*) distributed across the region (Daban *et al.*, 2021; Kabasakal *et al.* 2024e, 2025b) – we propose that the entire SoM be declared an ISRA to protect the taxonomic diversity of these sensitive species in an area undergoing severe environmental degradation.

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PRIDNENE HRUSTANČNICE V MARMARSKEM MORJU: POSODOBLJENA INVENTARIZACIJA, TAKSONOMSKA VPRAŠANJA IN OKOLJSKE POSLEDICE

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POVZETEK

Pričujoča raziskava temelji na vzorcih 16 vrst hrustančnic (devet vrst morskih psov in sedem vrst skatov), pridobljenih med letoma 2014 in 2024 v Marmarskem morju (SoM). V istem obdobju so drugi raziskovalci na istem območju zabeležili še dodatnih devet vrst (šest vrst morskih psov in tri vrste skatov). V zadnjih 100 letih je bilo na območju SoM tako zabeleženih 32 vrst pridnenih hrustančnic (16 vrst morskih psov in 16 vrst skatov), vendar uporaba meril za „potrjeno ali nepotrjeno prisotnost na podlagi dokazov" trenutno število zmanjša na 25 (15 vrst morskih psov, 10 vrst skatov). Analiza glavnih komponent (PCA) kaže, da je prilagodljivost plitvejšim vodam zdaj ključnega pomena za prostorsko porazdelitev pridnenih hrustančnic v morskem okolju. Ta premik jasno kaže, kako dramatično so degradacija okolja, onesnaževanje morja in deoksigenacija v zadnjih 40 letih zmanjšali favno hrustančnic v regiji, predvsem pridnenih vrst, kar poudarja potencialno uničujoč vpliv takšne degradacije na biotsko raznovrstnost.

Ključne besede: Elasmobranchii, preživetje, ohranjanje, inventarizacija, Marmarsko morje, Turčija

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